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Claims

[c1] A method of forming a tantalum-nitride diffusion barrier region on a low-k material substrate, the method comprising the steps of:
forming a protective layer on the low-k material substrate by plasma-enhanced atomic layer deposition (PE-ALD) from a tantalum-based precursor and a nitrogen plasma; and
forming a subsequent substantially stoichiometric tantalum-nitride diffusion barrier layer by PE-ALD from the tantalum-based precursor and a plasma of hydrogen and nitrogen.

[c2] The method of claim 1, wherein the tantalum-based precursor is selected from the group consisting of: tantalum pentachloride ($TaCl_5$), tantalum pentaiodide (TaI_5), tantalum pentafluoride (TaF_5), and tantalum pentabromide ($TaBr_5$).

[c3] The method of claim 1, wherein each forming step further includes:
exposing the substrate to the tantalum-based precursor prior to the PE-ALD in a chamber; and
evacuating the chamber after the PE-ALD.

[c4] The method of claim 1, wherein the protective layer forming step further includes providing a carrier gas for the tantalum-based precursor.

[c5] The method of claim 1, wherein the protective layer includes a higher content of nitrogen than tantalum.

[c6] The method of claim 1, wherein the protective layer forming step includes exposing the low-k material substrate for greater than 1000 Langmuirs.

[c7] The method of claim 1, wherein the low-k material substrate is selected from the group consisting of: silicon dioxide (SiO_2) and hydro-fluoric (HF) dipped silicon (Si).

[c8] The method of claim 1, wherein the tantalum-nitride diffusion barrier layer is thicker than the protective layer.

[c9] A method of forming a tantalum-nitride diffusion barrier region on a low-k material substrate, the method comprising the steps of:
forming a protective layer on the low-k material substrate by conducting a first number of first cycles in a chamber, each first cycle including:
exposing the substrate to a tantalum-based precursor,
evacuating the chamber,
plasma-enhanced atomic layer depositing (PE-ALD) from

the tantalum-based precursor and a nitrogen plasma, and

evacuating the chamber; and

forming a subsequent substantially stoichiometric tantalum-nitride diffusion barrier layer by conducting a second number of second cycles in the chamber, each second cycle including:

exposing the substrate to a tantalum-based precursor,

evacuating the chamber,

PE-ALD from the tantalum-based precursor and a plasma of hydrogen and nitrogen, and

evacuating the chamber.

[c10] The method of claim 9, wherein the tantalum-based precursor is selected from the group consisting of: tantalum penta-chloride ($TaCl_5$), tantalum penta-iodide (TaI_5), tantalum penta-fluoride (TaF_5), and tantalum pentabromide ($TaBr_5$).

[c11] The method of claim 9, wherein the exposing steps further include providing a carrier gas for the tantalum-based precursor.

[c12] The method of claim 11, wherein the carrier gas includes argon.

[c13] The method of claim 9, wherein the protective layer in-

cludes a nitrogen content greater than a tantalum content.

[c14] The method of claim 9, wherein the protective layer forming step includes exposing the low-k material substrate for greater than 1000 Langmuirs.

[c15] The method of claim 9, wherein the substrate is selected from the group consisting of: silicon dioxide (SiO_2), hydro-fluoric (HF) dipped silicon (Si) and a low-k material.

[c16] The method of claim 9, wherein the first number of cycles is less than the second number of cycles.

[c17] A tantalum-nitride diffusion barrier region for use with a low-k material, the region comprising:
a protective layer adjacent the low-k material, the protective layer including a tantalum-nitride material having a nitrogen content greater than a tantalum content; and
a substantially stoichiometric tantalum-nitride diffusion barrier layer adjacent the protective layer.

[c18] The barrier layer of claim 17, wherein there is substantially no diffusion of the low-k material and the protective layer.

[c19] The barrier layer of claim 17, wherein the tantalum-nitride material is selected from the group consisting of:

Ta_3N_5, Ta_4N_5 and Ta_5N_6.

[c20] The barrier layer of claim 17, wherein the protective layer has a thermal stability of greater than approximately 820°C.